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Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival

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Executive Summary

BACKGROUND

For thousands of years, North America's Columbia River salmon runs were the most abundant on Earth. The salmon evolved in a setting of many long- and short-term environmental changes and disruptions. With the introduction of an industrial-based economy to the region in the late nineteenth century, the scale and the rate of environmental variability in the basin changed. The creation of impoundments on the Columbia River and its tributaries, dam operations, commercial fishing, logging, diversions for irrigated agriculture, and human population growth have altered the Columbia's pre-settlement flow regime and have reduced the quality of salmon habitat across the river basin. There have been attendant declines—including some extinctions—in the populations of all resident salmon species. Annual salmon and steelhead returns to the Columbia River estuary were estimated to have been as high as 16 million fish per year during the late 1800s. The returns have dwindled over time, dropping to near one million fish per year in the 1990s. These numbers rebounded in the late 1990s and early 2000s, largely because that time frame coincided with a period of favorable ocean conditions for salmon. The majority of returns today consist of hatchery-reared fish. Many of these salmon are currently listed as threatened and endangered pursuant to the federal Endangered Species Act.

The Columbia River makes up part of a large (basin size of roughly 250,000 square miles) ecological system with many features that vary naturally on several different time scales. In addition to natural ecological variability, salmon are affected by human-induced changes such as water diversions and water control structures. Furthermore, Columbia River salmon spend most of their lives in the highly dynamic Pacific Ocean. The combination of these and other factors presents a setting of extraordinary variability and uncertainty for Columbia River salmon. The life cycles of Columbia River salmon (there are several different species and sub-species) have been intensively studied. In fact, Columbia River salmon are among the world's most carefully studied fish species, and this research has yielded an excellent understanding of salmon physiology and migratory behavior.

The Washington State Department of Ecology issues water use permits for the portion of the Columbia River that flows through the State of Washington. Water withdrawal permit decisions must be balanced with the state's obligation to protect and enhance the quality of the natural environment, including salmon habitat. The department considers scientific knowledge of salmon and environmental variables in making permitting decisions. That body of knowledge, as extensive and thorough as it may be, is imperfect and contains some competing theories, models, and perspectives.

This is the context in which the Washington State Department of Ecology requested that the National Research Council (NRC) provide advice regarding salmon and water management decisions. In response to this request, the National Research Council reviewed and evaluated existing scientific data and analyses related to fish species listed under the Endangered Species Act in the Columbia River basin, and reviewed and evaluated environmental parameters critical to the survival and recovery of listed fish species. The cumulative effects and the risks to the survival of listed fish species of potential future water withdrawals of between approximately 250,000 acre-feet and 1,300,000 acre-feet per year were also evaluated. There are currently many pending water withdrawal permit applications along the Columbia River in the State of Washington. The total volume of water represented by these applications falls within this 250,000—1,300,000 acre-feet per year range. In addition, the effects of proposed management criteria, specific diversion quantities, and specific features of potential water management alternatives provided by the State of Washington were to be evaluated. To conduct the study, the NRC appointed the ad hoc *Committee on Water Resources Management, Instream Flows, and Salmon Survival in the Columbia River.* This report's Preface contains additional information about the study process, and Chapter 1 includes verbatim the committee's statement of task.

SALMON AND ENVIRONMENTAL PARAMETERS

There are competing scientific hypotheses and models regarding the effects of environmental forces on Columbia River salmon. River velocity and water temperature are of particular interest to fisheries scientists, water managers, and interest groups, as these factors influence the migratory behavior of salmonids. Several computer models have been used to simulate the effects of river flows (especially water velocity) and temperature on the migratory speed and survival of smolt (young salmon ready to migrate from fresh water to the sea). These models ascribe different levels of importance to river discharge and temperature and their effects on migratory conditions for juvenile salmonids. Selecting the "best" model of salmon-environmental relationships was neither part of this study nor was it critical to its completion. Several scientists presented analyses and models in open public meetings for consideration in this study. These presentations were used as background information for considering the degree to which proposed future water extractions may pose increased risks to the survival of endangered fish species. This information, along with the body of scientific evaluations of Columbia River salmon and their habitat, portrays a complex system of interacting environmental variables that influence the rates of salmon smolt survival on their downstream journey through the Columbia River hydrosystem. **Within the body of scientific literature reviewed as part of this study, the relative importance of various environmental variables on smolt survival is not clearly established. When river flows become critically low or water temperatures excessively high, however, pronounced changes in salmon migratory behavior and lower survival rates are expected.**

COLUMBIA RIVER FLOWS AND WITHDRAWALS

Changes to the Annual Hydrograph

The annual flow patterns of the Columbia River underwent a substantial transformation during the twentieth century. At the beginning of the twentieth century, the river's flows exhibited great seasonality, with roughly 75 percent of the Columbia's annual flows occurring during summer months (April-September) and roughly 25 percent of annual flows occurring during winter months (October-March). The river's annual discharge is roughly 190 million acre-feet per year. The pattern of annual flows changed in response to the construction of numerous Columbia River mainstem and tributary impoundments, and the subsequent operations of this water control system. The system is known as the Federal Columbia River Power System (FCRPS), and the principal original purposes underlying its construction were to provide hydroelectricity, irrigation, and flood control benefits. Construction of some of the system's large mainstem projects, such as Grand Coulee and Bonneville, began in the 1930s. The post-World War II period saw a burst in project authorization and construction of additional large projects. Other projects were built in connection with the Canada-U.S. Columbia River Treaty signed in 1961. The hydrological implications of the system's construction were tremendous. As the system's water control projects came on line, annual flows of the Columbia became and less and less seasonal, as the differences between summer and winter flows were reduced in order to provide reliable, year-round hydropower generation and distribution. In the late 1970s, the Columbia's annual flows had been modified such that they were divided roughly evenly between summer and winter, as compared to the 75:25 ratio that had existed at the beginning of the twentieth century. In addition to this "flattening" of the annual Columbia River hydrograph, other key impacts of the construction and operations of the hydropower system were a decrease in water velocities, a change in the size and orientation of the Columbia River plume, and major changes to limnology and nutritional pathways in the Columbia River estuary and its food web. All these changes have likely had significant effects on the early ocean survival of juvenile fish leaving the Columbia River. Passage of environmental legislation such as the National Environmental Policy Act (1969) and the Endangered Species Act (1973) resulted in changes in operational patterns and priorities. "Flow targets" were established by federal and state agencies in an effort to sustain and recover salmon habitat and populations that had declined over time. The FCRPS today is operated primarily to provide benefits in terms of flood control, hydropower, and instream flows.

This study's focus was on the implications of potential additional water withdrawals (which would be primarily for irrigated agriculture) from the mainstem Columbia River for salmon survival. The study charge did not call for an examination of the hydrologic impacts of consumptive withdrawals in comparison with other actions, such as the creation of impoundments, dam operations, or changes in land cover.

Prospective Additional Water Withdrawals

Of special interest within this study was the consideration of the effects and risks to salmonid survival of a specific range of possible additional water withdrawals, ranging from 250,000 acre feet per year to 1,300,000 acre-feet per year. The latter figure represents roughly 28 percent of the total volume of water permits that have been issued to present by the State of Washington for surface water withdrawals from the Columbia River and groundwater withdrawals from the zone within one mile of the river. The effects of these proposed withdrawals and their attendant risks for the survival of a specific species will vary considerably depending upon Columbia River flow levels. Despite construction and operations of the hydropower system, the river still exhibits considerable flow variations on daily, seasonal, and annual time scales. Under current conditions, less than one percent of total annual withdrawals are made during January. By contrast, during July—the month of highest withdrawals—about 18 percent of annual withdrawals from the Columbia River in the State of Washington are made. The seasonality of water withdrawals is of utmost importance when considering how Columbia River water withdrawals affect salmon survival rates.

Many calculations and speculations could be made with regard to the range of prospective additional withdrawals considered in this study. Assuming that the monthly pattern of withdrawals from the mainstem Columbia River continues essentially unchanged, and assuming that the maximum amount of prospective withdrawals in the range considered in this study (maximum of 1,300,000 acre-feet per year) is diverted, additional withdrawals of roughly 2,600 acre-feet in January and roughly 234,000 acre-feet in July would result. The effects of these prospective additional January withdrawals (2,600 acre-feet) would result in withdrawals being less than one percent of mean January Columbia River flow. The effects of these prospective additional withdrawals in July (234,000 acre-feet), when river flows are lower, would increase July withdrawals from their current value of roughly 6.8 percent of mean Columbia River flows to roughly 8.6 percent of mean Columbia River flows. Under *minimum* July flow conditions, the effects would be even greater: the upper end of the proposed range of diversions would increase current July withdrawals from roughly 16.6 percent to roughly 21 percent of Columbia River *minimum* flows. Water temperature is also a concern. Columbia River water temperatures have been increasing for decades, and those temperatures are at their highest during summer months (when demand for extractions is also at or near its peak). Water quality is also an issue, as return flows from irrigated agriculture and urban activities are of degraded quality and could affect fish that are stressed already from high water temperatures and longer travel times.

The scale of the Columbia River basin and current limits of scientific understanding of salmon and their habitat inhibit reliable, precisely quantified predictions of how additional water withdrawals will affect risks to salmon survival. Nevertheless, further reductions in Columbia River flows during low-flow periods will increase those risks, especially since most of those withdrawals would occur during a critical period for those salmon species that are migrating through the mainstem Columbia River. There are differences in the migration patterns and timing of the Columbia River's listed salmon species and sub-species. Accordingly, only those salmon populations that migrate (downstream or upstream) through the Columbia River corridor during critical low-flow periods or years will be exposed to the greater risks entailed by additional withdrawals and reductions in discharge. Examples of these populations include subyearling ocean type Chinook from the Snake and Columbia rivers, adult Snake and Columbia River summer Chinook, adult Snake and Columbia River steelhead, and adult sockeye salmon.

Columbia River salmon today are at a critical point. The basin's salmon populations have been in steady decline over the past century, and scientific evidence demonstrates that environmental and biological thresholds important to salmon—such as water temperature—are being reached, or in some cases exceeded. Salmon are more likely to be imperiled during late summer on the Columbia River, as they experience pronounced changes in migratory behavior and survival rates when river flow becomes critically low or water temperature becomes too high. Further decreases in flows or increases in water temperature are likely to reduce survival rates. Trends such as human population growth in the region and prospective regional climate warming further increase risks regarding salmon survival.

Decisions regarding the issue of additional water withdrawal permits are matters of public policy, but if additional permits are issued, they should include specific conditions that allow withdrawals to be discontinued during critical periods. Allowing for additional withdrawals during the critical periods of high demand, low flows, and comparatively high water temperatures identified in this report would increase risks of survivability to listed salmon stocks and would reduce management flexibility during these periods.

WATER MANAGEMENT INSTITUTIONS

A Joint Forum for Considering Water Withdrawal Applications

The Columbia River basin is a single hydrologic unit extending over seven U.S. states, many Indian reservations, and one Canadian province. Water permitting decisions are made by basin states with few obligations or attempts to make those decisions in a spatially-coordinated manner across the entire basin. This fragmented basis for making water rights permitting decisions represents a barrier to better decision making in this realm. It also inhibits consideration of the cumulative effects of additional small, individual withdrawals. The effects of any one newly authorized individual water withdrawal from the Columbia River on flows and temperature are likely to be minimal. The effects of additional small diversions accumulate, however, and will eventually have serious consequences for salmon, especially when interacting with variables such as climate, ocean conditions, and human population growth. The current "case by case" approach for evaluating the effect of water permits on salmon can be likened to a beaver felling a tree—the effect of any single wood chip removed by the beaver on the health of the tree is slight and indeterminable. Critical thresholds, however, are crossed as the tree is girdled, reducing growth and causing mortality of major branches, or eventually removing enough wood to fell the tree. Every bite has only a small effect in itself, but each one contributes to the tree's eventual felling. Columbia River salmon are being subjected to a similar process. In isolation, small additional water withdrawals each have an imperceptible effect on survival rates of salmon; but the cumulative effects of many small, additional individual water withdrawals throughout the Columbia River basin collectively could push salmon across life-threatening thresholds, particularly in critical periods of high demand and low flows. Decreases in Columbia River flows have been caused by a small number of large diversions along the river—the long-approved large diversions for the Columbia Basin Project clearly dominate historical diversions—along with a large number of small, individual actions. A process in which water rights permitting applications throughout the basin are considered apart from this phenomenon of cumulative effects has contributed to salmon declines and may be contributing to political tensions. Decisions regarding prospective additional diversions should be considered with an understanding of existing and potential future diversions across the entire basin, and should be subjected to professional and public scrutiny, a consideration of risk factors, and system-wide equities. The lack of such a basin-wide framework also tends to discourage efforts at conservation and better management, since such measures employed in one state or other entity will have limited effects if other states and entities do not enact similar measures.

The State of Washington and other basin jurisdictions should convene a joint forum for documenting and discussing the environmental and other consequences of proposed water diversions that exceed a specified threshold. This forum could be convened within the existing Northwest Power and Conservation Council, which includes broad representation of political entities from across the basin. The council has accomplished good things, and discussions of water permit applications could be integrated into its resource management responsibilities. Limitations of convening this forum within the council include possible administrative and legal complications of extending the council's functions. Convening the forum within a new, simple, framework could offer the advantage of greater flexibility and a clearer focus of responsibilities and obligations.

Better Management of Existing Water Supplies

Water management approaches such as water conservation and associated transfers, conjunctive use of groundwater, water markets, water banks, and environmental water accounts have the potential to support regional economic growth without requiring additional Columbia River water diversions. These approaches can help transfer water between willing buyers and willing sellers and can be useful in helping shift water in response to changing economic conditions and priorities, as well as during periods of shortage. Physically, they may entail transfers of water in conveyance facilities, or the storage of water in a reservoir or groundwater reserve to be used later during a period of high demand. In some cases they may require the construction of conveyance and storage facilities. These approaches can be important in promoting a prosperous Columbia River basin economy that meets human needs while sustaining viable salmon populations and a healthy Columbia River ecosystem. Water supplies procured through these means could augment both water deliveries and instream flows. To be effective, such systems must consider and devise safeguards for preventing undue harm to third parties. They are also likely to require investments in physical infrastructure and in human resources. **The State of Washington and other Columbia River basin entities should continue to explore prospects for water transfers and other market-based programs as alternatives to additional withdrawals.**

MAKING COLUMBIA RIVER MANAGEMENT DECISIONS

Washington State Department of Ecology Water Management Scenarios

The water management scenarios proposed by the Washington State Department of Ecology and that were considered in this study contained many assumptions and actions related to water withdrawal quantities, management actions, and water use fees (key features of the scenarios, and comments that resulted from this study, are listed below; Appendix A lists these scenarios in their entirety). Some of the scenarios promote adaptive management concepts, which is appropriate and encouraging. Several possible management actions did not contain enough specificity to enable detailed evaluation. A pervasive aspect of the scenarios is the lack of comprehensive, basin-wide consideration of water uses and needs as a context for evaluating withdrawal permit applications.

Key features of the scenarios, along with commentary and evaluation, are listed below.

- *Conversion of interruptible to uninterruptible water rights (Scenarios 1-4).*

The needs of some users (especially growers of perennial crops) for uninterruptible withdrawals are understandable. The downside of such a system, however, is that uninterruptible status makes adaptive responses in periods of stress more difficult. Uninterruptible water rights are pre-1980 state law water rights that have priority over mainstem, instream flow rights that were established in 1980. These rights stand in contrast to interruptible water rights, which may be curtailed under certain low-flow conditions to protect mainstem, instream flows.

The conversion of water rights to uninterruptible status will decrease flexibility of the system during critical periods of low flows and comparatively high water temperatures. Conversions to uninterruptible rights, during these critical periods, are not recommended.

- *Criteria for state-of-the-art efficiency (Scenarios 1-4).*

The criteria for assessing the state-of-the-art (water use) efficiency measures are not described. In addition, organizational responsibility for making that evaluation is not specified.

- *Re-evaluation at 10 and 20 years (Scenarios 1-3).*

The idea of re-evaluating the scenarios periodically is excellent and is consistent with adaptive management principles. For this re-evaluation to be meaningful, decisions should be able to be adjusted if evaluation calls for such. No evidence of any such reversibility was provided. In some cases, more frequent re-evaluations may be in order.

- *Monitoring and metering (Scenarios 1-3).*

Monitoring for compliance with standards and water metering are also excellent ideas and could be accomplished as a part of this report's recommended basin-wide joint forum for discussing Columbia River basin water permit applications.

- *Charges for water rights (Scenarios 2-4).*

Charges for water rights appear to be arbitrarily chosen and out of proportion to the probable costs of mitigation and the value of water. For example, Scenario 2 specifies a charge of $10 per acre-foot per year to be used (among other things) to acquire mitigation water in low-water years. Even in high-water years, the economic value of out-of-stream water is greater than $10 per acre-foot per year, and this value increases in low-water years. This scenario seemingly poses selling water rights for $10 per acre-foot per year, when water may later have to be purchased for several times that amount.

- *Water markets.*

Proposals within the scenarios to establish water markets and water banks are appealing, as they offer potential improvements over existing water allocation systems. However, restricting markets to the Columbia River mainstem, and only to the State of Washington, is narrowly construed. For example, the Department of Ecology already allows for 600,000 acre-feet per year to be used by Oregon, but no allowance is made for uses in Idaho, Montana, Canada, or by tribal groups. Efforts toward developing water markets should be complemented with efforts to evaluate third-party effects and to design proposals for compensating users indirectly harmed by water rights transfers.

- *Structural storage measures.*

Structural measures imply that tributaries are to be used for additional storage, but ecological habitat and conditions in tributaries are important for many reasons, including their relationship to Columbia River salmon survival. Tributaries should be considered for protection and for mitigation, as well.

- *Scenario 5.*

This scenario was labeled a "no action" scenario, yet it prescribes new actions in that it allows for additional water withdrawal permits. The notion of consulting with fishery managers is good; however, no mention is made of criteria for the evaluation, how the results of the evaluation might be enforced, who decides how much mitigation is needed, and what—if any—limits on new permits might be enacted.

- *Mitigation.*

"Mitigation" measures are suggested in most of the management scenarios. Although the idea of "mitigating" impacts is attractive, the reality of most mitigation measures is that they are not well coordinated; that is, a management agency may attempt to offset harmful impacts of water withdrawals in one part of a river system with mitigation measures (e.g., ecosystem restoration) elsewhere. The ultimate outcomes of such varying actions, however, are difficult to accurately predict, measure, and compare (if indeed they are ever measured and meaningfully compared, which they often are not), thus making it difficult to determine if "mitigation" was actually achieved.

Science and Decision Making

The management of Columbia River salmon is an exceedingly complex public policy issue. The creation of comprehensive management strategies that enhance viable salmon populations, that calm disputes, and that meet human and economic demands will likely require a flexible and collaborative decision making approach that involves scientists, managers, and decision makers. Science has contributed greatly to the collective knowledge of Columbia River salmon, but "better" or "more" scientific information will not necessarily lead to the resolution of disputes or to better management decisions. **Sound, comprehensive salmon management strategies will depend not only on science, but also on a willingness of elected and duly appointed leaders and managers to take actions in the face of uncertainties**. It will also depend upon scientists and managers working in a process in which managers and elected officials help frame scientific investigations and inquiry. The scientific knowledge of Columbia River salmon is as extensive as for any other fish species in the world. Improvements in salmon habitat and return rates will require a willingness to employ existing scientific knowledge—despite its imperfections—to address some of the factors that scientific research suggests have led to their declines. A process in which scientists monitor outcomes of management actions and provide feedback to stakeholders and decision makers (who then adjust management actions accordingly—generally referred to as "adaptive management") will be instrumental in helping understand how additional scientific research can best support management decisions.